



# PROCEEDINGS OF THE XI INTERNATIONAL CONGRESS OF EGYPTOLOGISTS

Florence, Italy 23-30 August 2015

**MUSEO EGIZIO FIRENZE**

Florence Egyptian Museum

edited by  
**Gloria Rosati and Maria Cristina Guidotti**



**ARCHAEOPRESS EGYPTOLOGY 19**

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INTERNATIONAL CONGRESS  
OF EGYPTOLOGISTS XI

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**MUSEO EGIZIO FIRENZE**  
**FLORENCE EGYPTIAN MUSEUM**

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CENTER FOR ANCIENT MEDITERRANEAN  
AND NEAR EASTERN STUDIES



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# Contents

XI International Congress of Egyptologists .....	x
Preface .....	xiii
<b>Papers</b>	
Development of Old Kingdom pottery: three cases studies ('Cemetery of the Workers', Heit el-Ghurab and the Khentkawes Town).....	1
Sherif M. Abdelmoniem	
Of Min and moon – cosmological concepts in the Temple of Athribis (Upper Egypt) .....	7
Victoria Altmann-Wendling	
Les relations entre l'horloge stellaire diagonale et le corpus des Textes des Sarcophages dans le sarcophage intérieur de Mésehti : le temps et les décans .....	14
Bernard Arquier	
The Qubbet el-Hawa casting moulds – Late Period bronze working at the First Cataract .....	19
Johannes Auenmüller	
Overlapping and contradictory narratives in Ancient Egyptian visual programs .....	26
Jennifer Miyuki Babcock	
Sāmānu as a human disease in Mesopotamia and Egypt .....	29
Susanne Beck	
The pyramid as a journey – cultic encounters between father and son in the Pyramid of Pepy I.....	35
Nils Billing	
The Ancient Egyptian dialects in light of the Greek transcriptions of Egyptian anthroponyms .....	41
Ana Isabel Blasco Torres	
Dalla sabbia alla teca: esempi di interventi conservativi eseguiti su alcuni papiri del Museo Egizio di Firenze.....	46
Paola Boffula Alimeni	
New evidence on the king's son Intefmose from Dra Abu el-Naga: a preliminary report.....	53
Francisco L. Borrego Gallardo	
The Merenptah Sarcophagi restoration project.....	59
Edwin C. Brock and Lyla Pinch Brock	
Egyptian names and networks in <i>Trismegistos</i> (800 BC – AD 800).....	64
Yanne Broux	
The Ptolemaic dedication of Archepolis in the Bibliotheca Alexandrina: materiality and text .....	69
Patricia A. Butz	
Bernard V. Bothmer and Ptolemaic sculpture: papers on Ptolemaic art from his archives held at the Università degli Studi di Milano .....	75
Giorgia Cafici	
The Tell el-Maskhuta Project .....	81
Giuseppina Capriotti Vittozzi and Andrea Angelini	
Silence in the <i>Tale of the Eloquent Peasant</i> : themes and problems .....	87
Ilaria Cariddi	
Progetto Butehamon. Prospettive e ricerche nella necropoli tebana.....	92
Giacomo Cavillier	
Notes on the inscribed Old and Middle Kingdom coffins in the Egyptian Turin Museum .....	103
Emanuele M. Ciampini	

<b>Rethinking Egyptian animal worship (c. 3000 BC – c. 300 AD): towards a historical-religious perspective.....</b>	<b>107</b>
Angelo Colonna	
<b>Before and after the Temple: the long-lived necropolis in the area of the Temple of Millions of Years of Amenhotep II – Western Thebes.....</b>	<b>112</b>
Anna Consonni, Tommaso Quirino and Angelo Sesana	
<b>Papyri with the Ritual of the Opening of the Mouth in the Egyptian Museum in Turin .....</b>	<b>120</b>
Federico Contardi	
<b>Notes for a building history of the temple of Ramesses II at Antinoe. The architectural investigation.....</b>	<b>124</b>
Michele Coppola	
<b>Animal mummies in South African collections .....</b>	<b>131</b>
Izak Cornelius, Salima Ikram, Ruhan Slabbert, Liani C. Swanepoel, Frank Teichert and Tiffany van Zyl	
<b>Nouvelle lecture d'une scène de la théogamie d'Hatshepsout .....</b>	<b>137</b>
Alice Coyette	
<b>Worship and places of worship in the Greco-Roman town at Marina El-Alamein.....</b>	<b>140</b>
Grażyna Bąkowska-Czerner and Rafał Czerner	
<b>Middle Kingdom coffin of Khnum from the National Museum of Warsaw .....</b>	<b>148</b>
Dorota Czerwik	
<b>Non-destructive analysis on 11 Egyptian blue faience tiles from the 2nd and 3rd Dynasties.....</b>	<b>154</b>
Joseph Davidovits and Frédéric Davidovits	
<b>Scenes from the Amduat on the funerary coffins and sarcophagi of the 21st Dynasty.....</b>	<b>159</b>
Cássio de Araújo Duarte	
<b>Votive pottery deposits found by the Spanish Mission at Dra Abu el-Naga .....</b>	<b>166</b>
Elena de Gregorio	
<b>The building activity of Pinudjem I at Thebes .....</b>	<b>172</b>
Gabriella Dembitz	
<b>The 'Book of Going Forth by Day' in the funerary chamber of Djehuty (TT 11): past, present, and future .....</b>	<b>177</b>
Lucía Díaz-Iglesias Llanos	
<b>The pre-Egyptological concept of Egypt as a challenge for Egyptology and the efforts to establish a research community .....</b>	<b>184</b>
Florian Ebeling	
<b>The Gebelein Archaeological Project, 2013–2016 .....</b>	<b>188</b>
Wojciech Ejsmond	
<b>Trois nouvelles harpes découvertes à Thèbes ouest: Quel apport pour l'égyptologie ? .....</b>	<b>192</b>
Sibylle Emerit	
<b>The 'pantheistic' deities. Report from research on iconography and role of polymorphic deities .....</b>	<b>198</b>
Grzegorz First	
<b>Études sur le cadre de vie d'une association religieuse dans l'Égypte gréco-romaine : l'exemple de Touna el-Gebel ...</b>	<b>203</b>
Mélanie C. Flossmann-Schütze	
<b>Forme di imitazione egizia nella decorazione architettonica di Nea Paphos.....</b>	<b>209</b>
Leonardo Fuduli	
<b>Ahmose-Sapair in Dra Abu el-Naga: old and new evidence .....</b>	<b>215</b>
José M. Galán	
<b>The Moon god Iah in ancient Egyptian religion .....</b>	<b>222</b>
Gudelia García-Fernández	
<b>Expression of loyalty to the king – A socio-cultural analysis of basilophoric personal names dating to the Old and Middle Kingdoms .....</b>	<b>228</b>
Christina Geisen	

<b>Love and gold in cross-cultural discourse in the Amarna letters</b> .....	233
Graciela Gestoso Singer	
<b>Some unpublished inscriptions from Quarry P at Hatnub</b> .....	237
Yannis Gourdon and Roland Enmarch	
<b>Names of eye parts in different text genres: a contribution to technical language in ancient Egypt</b> .....	242
Nadine Gräßler	
<b>The transformation of Theban Tomb 39 (TT39). A contribution from a conservation viewpoint in terms of its history after dynastic occupation</b> .....	247
Dulce María Grimaldi and Patricia Meehan	
<b>The complete corpus of viticulture and winemaking scenes from the ancient Egyptian private tombs</b> .....	254
Maria Rosa Guasch-Jané, Sofia Fonseca and Mahmoud Ibrahim	
<b>Des étoiles et des hommes : peurs, désirs, offrandes et prières</b> .....	260
Nadine Guilhou	
<b>Cracking a code: deciphering the marks of the royal necropolis workmen of the New Kingdom</b> .....	266
Ben Haring	
<b>The Egyptian Dionysus: Osiris and the development of theater in Ancient Egypt</b> .....	271
Allison Hedges	
<b>The Abydos Dynasty: an osteoarchaeological examination of human remains from the SIP royal cemetery</b> .....	276
Jane A. Hill, Maria A. Rosado and Joseph Wegner	
<b>You up – I down: orientational metaphors concerning ancient Egyptian Kingship in royal iconography and inscriptions</b> .....	283
Shih-Wei Hsu	
<b>Image processing. Elaboration and manipulation of the human figure in the <i>Pyramid Texts</i></b> .....	287
Francesca Iannarilli	
<b>Hieroglyphic inscriptions on precious objects: some notes on the correlation between text and support</b> .....	291
Agnese Iob	
<b>Predynastic precursors to the Festival of Drunkenness: beer, climate change, cow-goddesses, and the ideology of kingship</b> .....	296
Victoria Jensen	
<b>Crowdsourcing in Egyptology – images and annotations of Middle Kingdom private tombs</b> .....	303
Peter Kalchgruber and Lubica Hudáková	
<b>‘To build a temple in the beautiful white stone of Anu’. The use of Tura limestone in Theban architecture</b> .....	308
Christina Karlshausen and Thierry De Putter	
<b>The motif of the kiosk during the first half of the 18th dynasty</b> .....	313
Edyta Kopp	
<b>A heritage in peril: the threat to Egypt’s urban archaeological sites</b> .....	318
Peter Lacovara	
<b>Le <i>sḏm.f</i> circonstanciel. Une forme verbale rare en néo-égyptien littéraire</b> .....	320
Vincent Pierre-Michel Laisney	
<b>Amduat type papyri in the Pushkin State Museum of Fine Arts, Moscow</b> .....	325
Nika Lavrentyeva	
<b>Carving out identities in the Egyptian desert: self-presentation styles adopted by the ancient travelers of Kharga Oasis</b> .....	328
Nikolaos Lazaridis	
<b>Ya-t-il une « fabrique d’albâtre » et un atelier de tissage au Ramesseum ?</b> .....	333
Guy Lecuyot	



<b>Deux nouvelles ‘Recommandations aux prêtres’ datées de Ptolémée X Alexandre I<sup>er</sup></b> .....	339
Nicolas Leroux	
<b>Scenes representing temple rituals on some 21st Dynasty coffins</b> .....	345
Éva Liptay	
<b>Building B, a domestic construction at Tell el-Ghaba, North Sinai</b> .....	351
Silvia Lupo, Eduardo Crivelli Montero, Claudia Kohen and Eva Calomino	
<b>The Montecelio Obelisk in Rome</b> .....	357
Lise Manniche	
<b>The role of e-learning in Egyptology: ‘Hieroglyphs: Step-by-Step’ website as a case study</b> .....	362
Ahmed Mansour and Azza Ezzat	
<b>The function and importance of some special categories of stars in the Ancient Egyptian funerary texts, 1: <i>3h3h-</i> and <i>i3d-</i>stars</b> .....	368
Alicia Maravelia	
<b>Chapel of the tomb belonging to Amenhotep III’s Vizier, Amenhotep Huy. Asasif Tomb No. 28, Luxor-West Bank. Excavation results: ‘Vizier Amenhotep Huy Project’ (2009–2014)</b> .....	377
Francisco J. Martín-Valentín and Teresa Bedman	
<b>Objets découverts dans des tombes thébaines situées sous le Temple de Millions d’Années de Thoutmosis III à l’ouest de Louxor</b> .....	384
Javier Martínez Babón	
<b>Fish offerings found in Area 32 of the archaeological site of Oxyrhynchus (El-Bahnasa, Egypt)</b> .....	389
Maite Mascort Roca and Esther Pons Mellado	
<b>The <i>Akh-menu</i> of Thutmosis III at Karnak. The Sokarian Rooms</b> .....	394
Julie Masquelier-Loorius	
<b>The 13th Dynasty at Abydos: a royal tomb and its context</b> .....	399
Dawn McCormack	
<b>The transmission of the <i>Book of the Twelve Caverns</i></b> .....	405
Daniel M. Méndez Rodríguez	
<b>A new reading of Problem No. 53 in the Rhind Mathematical Papyrus. The limits of proportionality</b> .....	410
Marianne Michel	
<b>The <i>ang</i>-morphs in Coptic and their grammaticalization in Later Egyptian</b> .....	416
So Miyagawa	
<b>‘Augmented Reality’ technology and the dissemination of historical graffiti in the Temple of Debod</b> .....	422
Miguel Ángel Molinero Polo, Alfonso Martín Flores, Jorge Martín Gutiérrez, Cristóbal Ruiz Medina, Lucía Díaz-Iglesias Llanos, Fernando Guerra-Librero Fernández, Daniel Miguel Méndez Rodríguez, Luis Navarrete Ruiz, Manuel Rivas Fernández and Ovidia Soto Martín	
<b>The <i>Min Project</i>. First working seasons on the unpublished Tomb of Min (TT109) and Tomb Kampp -327-: the Tomb of May and a replica of the Tomb of Osiris</b> .....	427
Irene Morfini and Milagros Álvarez Sosa	
<b>Figurative vase painting from the First Intermediate Period through to the Fatimid Dynasty: a continuity?</b> .....	433
Maya Müller	
<b>Basic considerations on the construction of pyramids in the Old Kingdom</b> .....	437
Frank Müller-Römer	
<b>Die Verwendung von Münzen in pharaonischer Zeit</b> .....	441
Renate Müller-Wollermann	
<b>In the footsteps of Ricardo Caminos: rediscovering the ‘Speos of Gebel el Silsila’</b> .....	445
Maria Nilsson and Philippe Martinez	
<b>The folding cubit rod of Kha in Museo Egizio di Torino, S.8391</b> .....	450
Naoko Nishimoto	

<b>The mystery of the ‘high place’ from the <i>Abbott Papyrus</i> revealed? The results of the works of the Polish Cliff Mission at Deir el-Bahari 1999–2014.....</b>	<b>457</b>
Andrzej Niwiński	
<b>The mummies of the ‘Three Sisters’ in the Museo Egizio: a case study. Conservation and studies of textiles and bandages .....</b>	<b>462</b>
Cinzia Oliva and Matilde Borla	
<b>Technical aspects of faience from Hierakonpolis, Egypt – a preliminary report .....</b>	<b>468</b>
Marina Panagiotaki, Elizabeth Walters, Yannis Maniatis and Anna Tsoupra	
<b><i>Horus Seneferou ka-s</i> : quand le dernier souverain de la Ire dynastie devient la première femme pharaon de l’Histoire à porter un nom d’Horus .....</b>	<b>472</b>
Jean-Pierre Pätznick	
<b>The Herakleopolis Magna Project: seasons 2012–2015.....</b>	<b>480</b>
M. Carmen Pérez-Die	
<b>The Stelae Ridge cairns: a reassessment of the archaeological evidence .....</b>	<b>485</b>
Hannah Pethen	
<b>The Italian-Egyptian Mission at the Monastery of Abba Nefer at Manqabad: results of the first four seasons’ work.....</b>	<b>491</b>
Rosanna Pirelli, Ilaria Incordino, Paola Buzi and Anna Salsano	
<b><i>Wedjat-eyes</i> as a dating criterion for false doors and stelae to the early Middle Kingdom.....</b>	<b>499</b>
Melanie Pitkin	
<b>La collection égyptienne du Musée Sandelin à Saint-Omer (France).....</b>	<b>506</b>
Jean-Louis Podvin	
<b>Some remarks on the Egyptian reception of foreign military technology during the 18th Dynasty: a brief survey of the armour.....</b>	<b>513</b>
Alberto Maria Pollastrini	
<b>Medical re-enactments: Ancient Egyptian prescriptions from an emic viewpoint .....</b>	<b>519</b>
Tanja Pommerening	
<b>Textual layers in <i>Coffin Texts</i> spells 154–160 .....</b>	<b>527</b>
Gyula Priskin	
<b>The cat mummies of the <i>Società Africana d’Italia</i>: an archaeological, cultural and religious perspective .....</b>	<b>532</b>
Maria Diletta Pubblico	
<b>Khnum the Creator: a puzzling case of the transfer of an iconographic motif.....</b>	<b>538</b>
Maarten J. Raven	
<b>Temple ranks in the Fayyum during the Ptolemaic and Roman Periods: documentary sources and archaeological data.....</b>	<b>543</b>
Ilaria Rossetti	
<b>Le musée de Mallawi: état des lieux après les destructions et projets pour l’avenir .....</b>	<b>549</b>
Ashraf Alexandre Sadek	
<b>A new light on Coptic afterlife (O.4550 from the Coptic Museum in Cairo).....</b>	<b>553</b>
Hind Salah El-Din Somida Awad	
<b>The lost chapels of Elephantine. Preliminary results of a reconstruction study through archival documents .....</b>	<b>556</b>
Daniele Salvoldi and Simon Delvaux	
<b>Doors to the past. Rediscovering fragments in the new blockyard at Medinet Habu .....</b>	<b>563</b>
Julia Schmied	
<b>Les dépôts de fondation de la Vallée des Rois : nouvelles perspectives de recherche sur l’histoire de la nécropole royale du Nouvel Empire .....</b>	<b>568</b>
François C. A. Schmitt	

<b>Economic mentalities and Ancient Egyptian legal documents .....</b>	<b>576</b>
Alexander Schütze	
<b>Excavations in the ‘Temple of Millions of Years’ of Thutmosis III.....</b>	<b>581</b>
Myriam Seco Álvarez	
<b>Rituels funéraires au temps de Hatchepsout : le sanctuaire de la tombe de Djehouty et ses parallèles .....</b>	<b>587</b>
José M. Serrano	
<b>The so-called <i>Book of Two Ways</i> on a Middle Kingdom religious leather roll .....</b>	<b>594</b>
Wael Sherbiny	
<b>Ibyc. PMGF 287 and Ancient Egyptian love songs .....</b>	<b>597</b>
Anna Sofia	
<b>The <i>Physiologus</i> in Egypt.....</b>	<b>603</b>
Marco Stroppa	
<b>A survey of astronomical tables on Middle Kingdom coffin lids .....</b>	<b>608</b>
Sarah L. Symons	
<b>Blue painted pottery from a mid-18th Dynasty royal mud-brick structure in northwest Saqqara .....</b>	<b>613</b>
Kazumitsu Takahashi	
<b>Studies on BD 17 vignettes: iconographic typology of <i>Rw.tj</i>-scene (New Kingdom – Third Intermediate Period).....</b>	<b>619</b>
Mykola Tarasenko	
<b>Were components of Amarna composite statues made in separate workshops? .....</b>	<b>626</b>
Kristin Thompson	
<b>Research on Old Kingdom ‘dissimulation graphique’. World-view and categorization .....</b>	<b>633</b>
Simon Thuault	
<b>La funzione del tempio tolemaico di Deir el-Medina alla luce dell’archeologia.....</b>	<b>638</b>
Claudia Tirel Cena	
<b>The ‘geography’ of the <i>hierogrammateis</i>: the religious topography of the Western Harpoon (7th Nome of Lower Egypt) .....</b>	<b>644</b>
Elena Tiribilli	
<b>The Ancient Egyptian shabtis discovered in the regions of Roman <i>Illyricum</i> (<i>Dalmatia, Pannonia</i>) and <i>Istria</i>: provenance, collections, typological study and dating.....</b>	<b>650</b>
Mladen Tomorad	
<b>From Egypt to the Holy Land: first issues on the Egyptian collection in the <i>Studium Biblicum Franciscanum</i>, <i>Jerusalem</i> .....</b>	<b>656</b>
Benedetta Torrini	
<b>Tradition and innovation within the decoration program of the temple of Ramesses II at Gerf Hussein.....</b>	<b>661</b>
Martina Ullmann	
<b>The Egyptian Execration Statuettes (EES) Project.....</b>	<b>667</b>
Athena Van der Perre	
<b>A new long-term digital project on Hieratic and cursive hieroglyphs .....</b>	<b>671</b>
Ursula Verhoeven and Svenja A. Gülden	
<b>Hierakonpolis Faience, 2005–2013, with context and accompanying finds – a quest for chronology and possible use .....</b>	<b>676</b>
Elizabeth J. Walters, Amr El Gohary, Shelton S. Alexander, Richard R. Parizek, David P. Gold, Recep Cakir, Marina Panagiotaki, Yannis Maniatis and Anna Tsoupra	
<b>The Berlin Plans from the New Kingdom Period.....</b>	<b>680</b>
Yoshifumi Yasuoka	
<b>The career of Nakhtmin (TT 87) as revealed by his funerary cones .....</b>	<b>686</b>
Kento Zenihiro	

<b>Object biographies and political expectations: Egyptian artefacts, Welsh Heritage and the regional community museum.....</b>	<b>693</b>
Katharina Zinn	
<b>Who am I - and if so, how many? Some remarks on the 'j-augment' and language change.....</b>	<b>701</b>
Monika Zöllner-Engelhardt	
<b>Poster presentations</b>	
<b>Vocabulaire de l'Égyptien Ancien (VÉgA). Plateforme numérique de recherche lexicographique.....</b>	<b>709</b>
A. Almásy, Ch. Cassier, J. Chun-Hung-Kee, F. Contardi, M. Massiera, A. Nespoulous-Phalippou and Fr. Rouffet	
<b>Pottery from the early Roman rubbish dumps in Berenike harbour.....</b>	<b>711</b>
Agnieszka Dzwonek	
<b>A sequence of five 13th Dynasty structures at Memphis .....</b>	<b>714</b>
Rabee Eissa	
<b>Funerary culture of the Memphite region during the Early Dynastic Period .....</b>	<b>717</b>
Barbora Janulíková	
<b>3D-Reconstructions of Late Roman fortresses in Egypt.....</b>	<b>718</b>
Dmitry Karelin, Maria Karelina and Tatiana Zhitpeleva	
<b>The Roman Imperial cult temple at Luxor: its architecture and possible connection between Roman and Egyptian cultures .....</b>	<b>720</b>
Irina Kulikova and Dmitry Karelin	
<b>One of the earliest discovered houses at Memphis .....</b>	<b>722</b>
Hanan Mahmoud Mohamed	
<b>Reden und Rufe, are they kingly patterns? A first step towards an explanation of the origin(s) of speech captions in 'daily life' scenes in private tombs .....</b>	<b>724</b>
Aurore Motte	
<b>Étude pluridisciplinaire de têtes de momies (Lyon).....</b>	<b>725</b>
Annie Perraud, Matthieu Ménager, Pascale Richardin and Catherine Vieillescazes	
<b>Progetto Osiris: valorizzazione delle piccole collezioni egizie .....</b>	<b>727</b>
Massimiliana Pozzi Battaglia e Federica Scatena	
<b>Study and restoration of two mummies from the Moulins Museum .....</b>	<b>729</b>
Noëlle Timbart	
<b>List of papers presented at ICE XI.....</b>	<b>731</b>
Massimiliano Franci	

# The folding cubit rod of Kha in Museo Egizio di Torino, S.8391

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## Abstract

Much may be inferred about item S.8391, a folding cubit rod that belonged to Kha (TT 8, 18th Dynasty), by analyzing the results of the measurement survey conducted in 2011 from the perspective of woodwork.

When Schiaparelli discovered the rod, it was folded inside a leather bag with a strap. The extremely rare folding cubit rod was loved by Kha, who was the overseer of works in Deir el-Medina and its related sites, where it was in practical use. This rod folds in half with a simple bronze hinge at the center; there are absolutely no inscriptions. The carved tally marks are only rough divisions into palms and the digits, and compared with other rods, the cubit measure is somewhat long, so the rod's precision was in doubt. However, a metrological argument concerning the differences in the values of the palms and digits is proposed based on the presumed manner in which the wooden rod was created and actually used. The rod's total length is 527.6mm, not greatly different from that reported by Senigalliesi in 1961. The size of each measurement interval, which Senigalliesi did not report, suggests how the rod was made. The tally marks are fine white lines; the left-hand palm is 75mm long, which is the common measurement of one palm, subdivided into four digits that vary little in size. Taking this into account, it is unthinkable that the makers lacked the ability to make tally marks accurately. The variations of values were supposedly caused by the process of creating the hinge. The center interval, including the hinge, is especially small, at (36mm + 36mm =) 72mm. For example, if we assume a play of about 3mm, a commonly used value, the center interval would become 36mm + 36mm + 3mm = 75mm. The inclination of the lines and the variations in size indicate that tally marks were etched in the closed position. S.8391 can also be used as a half-cubit measure in a closed position, and the first palm on the left side can measure digits. Traces of trial and error in remaking the hinge were found. In this study, I discovered that the clever hinge that makes this cubit rod possible satisfies two contradictory requirements to realize this rare folding rod. The appearance of this folding cubit rod, with no inscriptions and purely functional design, shows that it took incalculable effort to make it a prized instrument for the owner.

## Keywords

New Kingdom; metrology; Thebes; woodworking; tools

## Introduction

The design processes of ancient Egyptian woodworking by anonymous artisans, including problems with their tools, are very interesting from the architectural point of view. Among the most interesting examples of ancient woodworking are pieces of ancient Egyptian furniture authenticated since the 1960s.

Superb technical drawings of Egyptian furniture have been produced in the past. Pioneers such as Baker and Wanscher, who were originally furniture makers, have bequeathed richly illustrated and authored books (Baker 1966; Wanscher 1980). In the second generation, Fischer and Killen produced valuable drawings (Fischer 1996; 1980-1994. See Herrmann 1996 for additional discussion). In addition, Eaton-Krauss discovered and revealed detailed scale drawings by Segal, an architect, who stayed in Cairo and produced them in 1935 (Eaton-Krauss 1989: 80-6, figs 1-4; Eaton-Krauss 1995: 90-2, figs 1-6; Eaton-Krauss 1997: 180, 183-4, figs 1-3; Eaton-Krauss 2008: 150-172, figs 1-33). Fortunately, she deposited Segal's drawings and notes in the Griffith Institute. Lovera (Leospo 1988: 154, fig. 206; Leospo 2001: 48, fig. 43) and Nicola (Leospo 1988: 122, fig. 161; Leospo *et al.* 1989: 40-81, figs 5-11, figs 14-20, figs 40-42, figs 52-53; Leospo 2001: 17, fig. 2; Nicola 1983: 60-1, figs 2-8) also produced fine detailed drawings of items of woodwork stored in Museo Egizio di Torino. However, there are few sources that provide the essential information for a detailed study of woodwork design processes, such as the components' seam lines or the size and position of the wooden pegs used in joinery.

Against this background, since 2000, I have surveyed and measured the pieces of furniture in the intact collection belonging to the architect Kha and his wife Merit, which is stored in Museo Egizio di Torino (Curto 1984; Donadoni Roveri 1988; Leospo 1983; Meskell 1998; Russo 2012; Scamuzzi 1965; Schiaparelli 1927; Vassilika 2010). These items can be

compared to those of King Tutankhamun. I believe that the Kha and Merit's furniture collection is important not only in the study of woodwork but also for investigating the relationship between furniture and social roles.

From the results of the measurement survey, I first make two-dimensional scale drawings, and then create an exploded view using axonometric drawings (Nishimoto 2000; Nishimoto 2012; Nishimoto 2014). I then use the component drawings to demonstrate the devotion and craftsmanship of ancient artisans through such aspects as the form, construction method, joinery, and differences in the materials of each component, as well as mechanisms such as locks.

These pieces of furniture frequently reveal signs of repair that show trial and error, and these signs of repair become keys to understanding noteworthy problem-solving processes. At that time, lumber was very scarce, and parts of other artifacts were frequently reused. We must pay attention when traces of reconstruction are found. Because craftsmen who handled precious lumber would have been honored to be entrusted with such careful work, signs of repair through trial and error show that it was unforeseeably difficult work, even if detailed plans had been made by experienced artisans.

The production process of Inv. No. S.8391, a folding cubit rod, may be inferred by analyzing the results of the measurement survey in 2011 from the perspective of woodwork. In the following paragraphs I would like to demonstrate how this rod was made, with the aid of scale drawings and diagrams.

## The folding cubit rod

Among the artifacts excavated from the tomb of Kha and Merit, there is an especially important item, even among those stored in Museo Egizio di Torino: the wooden folding cubit rod thought to have actually been used by the architect Kha (Curto

1984: 210; Donatelli 1988: 162, fig. 223; Goyon *et al.* 2004: 386; Schiaparelli 1927: 80, fig. 47; Senigalliesi 1961: 27, 32–3, 52, figs 4, 14–7, Table III; St. John 2000: 30; Vassilika 2010: 78–9, 83). When Schiaparelli discovered it, this cubit rod was folded in a soft, tanned leather bag with handles. It is thought that Kha carried it with him at all times. His artifacts include several gifts from kings and high officials, indicating his social status. Kha made a name for himself in the age of Amenhotep II and is known for serving three generations of kings, including Thutmose IV and Amenhotep III (Russo 2012: 23, 77–8; Trapani 2012: 159). His official position is inscribed on the leg of a folding stool, S.8509 (Baker 1966: 116, fig. 156; Curto 1984: 215; Killen 1980–1994, vol.1: unnumbered page, in a table listing the items of Turin Museum; Schiaparelli 1927: 114, fig. 94; Vassilika 2010: 103–5; Wanscher 1980: 21), and when one considers that the original purpose of this stool was for outdoor use, it seems to symbolize the position of overseer of the (construction) works at the Great Palace (Russo 2012: 74). Kha was neither royal, nor a nobleman. However, according to Russo, he was not only the supervisor of the artisans of Deir el-Medina who worked on the tombs in the Valley of the Kings, but also so special a person that his name was known outside Deir el-Medina as well (Russo 2012: 78).

Recognized examples of the folding mechanism in ancient Egypt include folding stools from the Middle Kingdom, and a great number have been discovered from the New Kingdom, aside from the aforementioned S.8509 (Baker 1966: 135–7, figs 195–9; El Gabry 2014; Killen 1980–1994, vol. 1: 40–3; pls 55–64; Wanscher 1980: 9–68). Others include a folding bed from the New Kingdom that King Tutankhamun carried on campaigns, which is a compact bed that features ingenious stacking and is stored in the Egyptian Museum in Cairo (Baker 1966: 104–5, figs 136–7; Carter and Mace 1923–1933, vol. 3: 111, pl. 32A; Desroches-Noblecourt 1963: 184–5, figs 107a, b; Killen

1980–1994, vol. 1: 33–4, pls 42–3, figs 15–7; Reeves 1990: 182; Nishimoto 2000. See also H. Carter’s Card No. 586-3 stored in the Griffith Institute). A model of a folding bed from the New Kingdom, Met No. 20.2.13a-c (Hayes 1959: 203, fig. 118; Scott 1944: 23), is also known.

The extremely rare folding cubit rod was loved by Kha, and it was employed for practical use. The entire rod is divided into seven intervals, and the leftmost of these is subdivided into four. The folding mechanism is compact for carrying, its movements are smooth, and it is a pleasure to use.

On cubit rod S.8391, which folds in half, there are absolutely no inscriptions. The carved tally marks are only rough divisions of the palm and the digits, and the length of one cubit is somewhat long, so its precision was in doubt. For a long time, this rod was disregarded by experts as an artifact with limited archaeological information (Sliwa 1975: 39).

However, as we begin to re-examine how the cubit rod was actually used in the Valley of the Kings, a detailed inspection of the only practical folding cubit rod yet discovered is probably essential for obtaining source material when studying the design methods of artisans. Goyon describes the cubit rods for practical use, but among those, only this eccentric cubit rod is illustrated (Goyon *et al.* 2004: 386, fig. 497).

**Observations**

Figure 1 shows the measurement scale drawing of S.8391. The rod, 20mm wide and 15mm high, has a characteristic pentagonal cross-section with a beveled edge. The total length is 527.6mm, not greatly different from the measurement reported by Senigalliesi in 1961, which was 528.634mm (Senigalliesi 1961: 52, Table III).

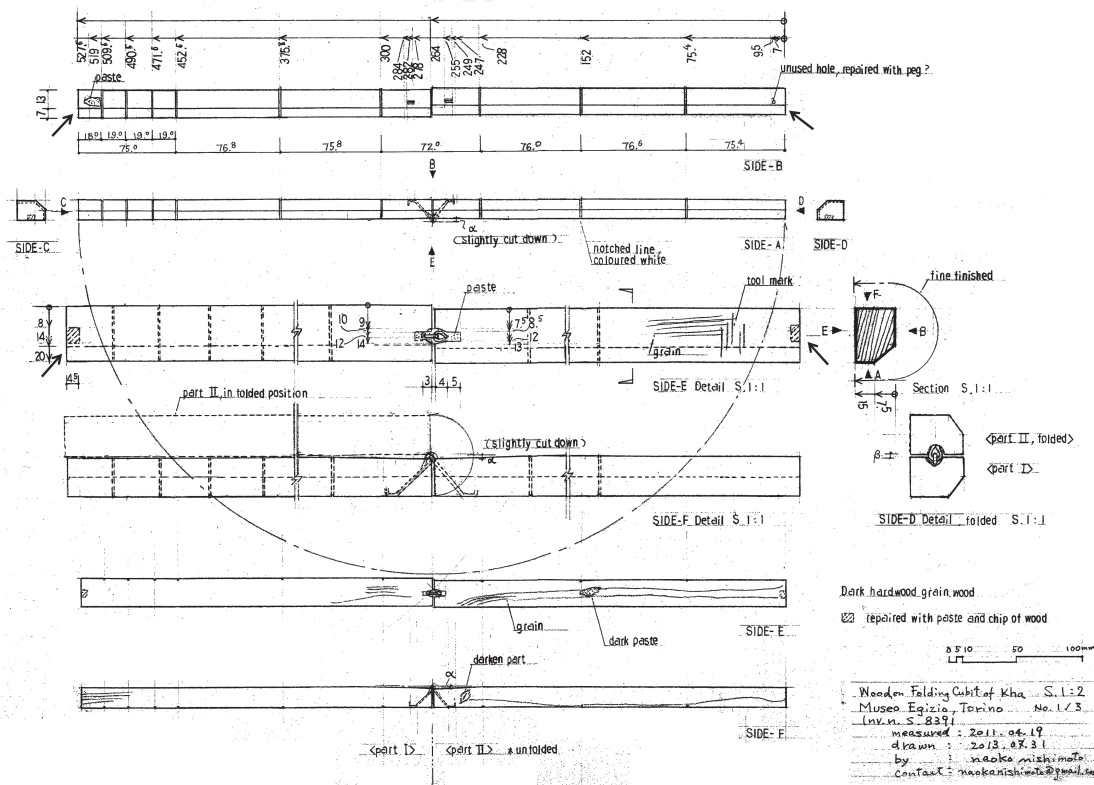


FIGURE 1: MEASUREMENT DRAWING OF FOLDING CUBIT ROD, INV. NO. S.8391, MUSEO EGIZIO DI TORINO.

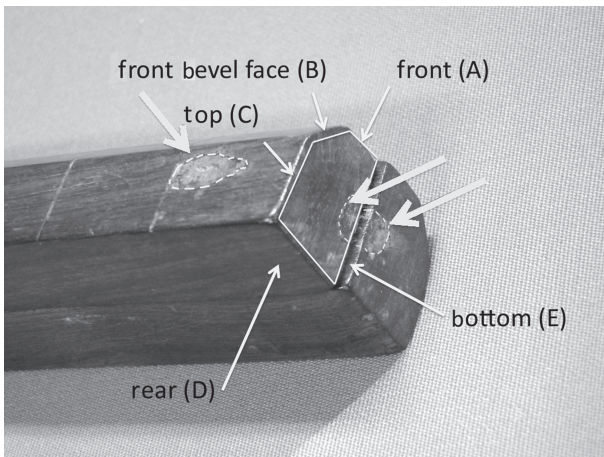


FIGURE 2: VIEW OF THE END, IN CLOSED POSITION.

Senigalliesi did not report the value of each measurement interval; therefore, I report the values for the first time here, as follows.

- 1st digit = 18.0mm
- 2nd digit = 19.0mm
- 3rd digit = 19.0mm
- 4th digit = 19.0mm

- 1st palm = 75.0mm (18mm + 19mm + 19mm + 19mm)
- 2nd palm = 76.8mm
- 3rd palm = 75.8mm
- 4th palm = 72.0mm
- 5th palm = 76.0mm
- 6th palm = 76.6mm
- 7th palm = 75.4mm

One palm is an average length of 75.37mm, and one digit is an average of 18.75mm.

The heavy, deep-maroon hardwood, acacia (Schiaparelli 1927: 80), is polished to a shine. The tally marks are notched lines, part of which have the remains of white pigment. With a clear, thin white tally mark on a hard and brightly polished dark-brown surface, it would have been very easy to see and use (Figure 2).

Museo Egizio di Torino also has Kha's gilt cubit rod, Inv. No. S.8647 (Curto 1984: 210; Russo 2012: 10–3; Senigalliesi 1961: 27 and 33–6, figs 5, 11, 18–24, Table III; Trapani 2012: 160–2, pl. 32.1; Vassilika 2010: 17), and the famous rod of Amenemope, Inv. No. 6347 (Curto 1984: 263; Donatelli 1988: 163, figs 220–1; Hirsch 2013: 34, fig. 7; Lorenzen 1966: pl. I; Senigalliesi 1961: 36–46, figs 6, 10, 13, and 25–30, Tables I, II and III), both of which have a pentagonal cross-section and are inscribed with hieroglyphs as votive rods. The total length of the gilt cubit rod is 523mm. This was a gift from Amenophis II.

The orientation of the cubit rod, from the hieroglyphs, is such that the front (A) as indicated in Figure 2 is an angled surface (Hirsch 2013: 15, fig. 2; Schlott 1969: 43). The subdivided palms of Amenemope's rod are on the right-hand side, but Kha's folding rod divides one palm into four digits on the left-hand side. The gilt cubit rod of Kha is also subdivided on the left-hand side. Although Kha's two rods have the left-hand subdivision in common, the two show considerable differences in the manner of segmentation.

On the folding cubit rod, the length of the leftmost digit is smaller than the others. Trapani stated with reference to the gilt cubit rod, 'Yet the engraving of the last palm is traced at a smaller interval in comparison with the others, so that it is likely that its width was determined by the total length of the cubit' (Trapani 2012: 161. However, note the careless confusion between Amenophis II and Amenophis III in conclusion; Trapani 2012: 167).

**Construction of the folding cubit rod**

An examination of the numerical measurements of the palms shows that the value of a palm interval on the left-hand end is 75mm, and the measurements of the remaining palms vary. These variations were supposedly caused by the process of creating the hinge. I will state my conjectural conclusions about the making of this rod and the construction of the folding mechanism based on the actual measurements of each interval of S.8391.

The values linked by arrows in Figure 3 have similar variations, showing the relationship of the point symmetry pivoting on the hinge in the center. From this, it is conjectured that the tally marks were notched in a closed position. It is also thought likely that this measure was also intended to be used when the rod was in a folded position.

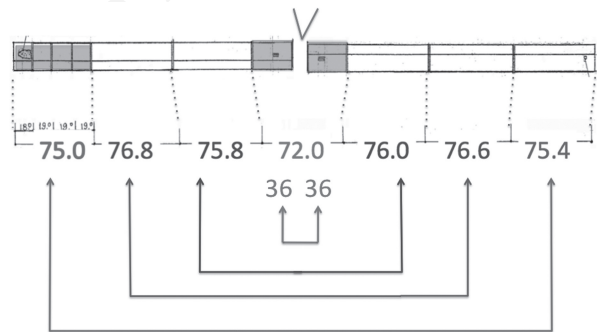


FIGURE 3: ASSUMED RELATIONSHIP BETWEEN TALLY MARKS, BASED ON SIZE.

If the values from the left-hand side are aligned, the center interval, including the hinge, is especially small, at (36mm + 36mm =) 72mm.

$$75.0 / 76.8 / 75.8 / \underline{36.0} / \text{hinge} / \underline{36.0} / 76.0 / 76.6 / 75.4$$

(units in mm)

As mentioned above, the tallies are delicate white lines; the left-hand palm is 75mm, which is the common measurement of one palm, and it is subdivided into four digits whose values have little variation. Taking this into account, it is unthinkable that the makers lacked the ability to make tally marks accurately. So why are there variations in the values?

Perhaps the artisans, from experience, tried to allow play between the segments beforehand for the sake of the folding hinge, as shown in Figure 3. In woodworking terminology, play indicates an 'allowance' for dimensions, in this instance, the 'clearance' created to prevent the two segments of the rod from jamming against each other and interrupting its rotation. Even now, play is often prepared ahead of time for items that rotate. For example, if we assume a play of about

3mm, an often-used value, the center interval would become  $36\text{mm} + 3\text{mm} + 36\text{mm} = 75\text{mm}$ . Perhaps the center interval was reduced because the artisan made the tally marks while taking the play into account. For reasons I will discuss below, the result was that the space allowed for play was eventually closed, and the interval became too small. If so, how did the inaccuracy of the other intervals come about?

As for the production process for making a rod to be used as a one-cubit measure when open and a half-cubit measure when closed, it is thought that a one-cubit-long rod was first made, which was then cut in half, and finally the hinge was made. This time, to prepare the aforementioned play, the artisan had to decide where to include the play segment. In other words, there was an option to shorten the half-cubit measures by half the length of the play, or to have the one-cubit measure extended by the length of the play. It is thought that the makers used a method of making the whole rod on the long side. Because the center interval was shrunk only by the length of the play, as mentioned above, the play-sized part was divided within the half cubit. If it were used to take preliminary measurements of materials, for example in carpentry, the thickness of a blade saw would be lost, so there is a rationality to its being larger to allow for this width in measurements.

### Clever hinge

Traces of repairs were found in the locations indicated by arrows on the top and on both ends (Figures 1 and 2). We cannot overlook the fact that the repair marks are clues to the knowledge of the artisans and the struggle for new designs at the time. These signs of repair clearly show that the hinge was remade, as I explain in detail below.

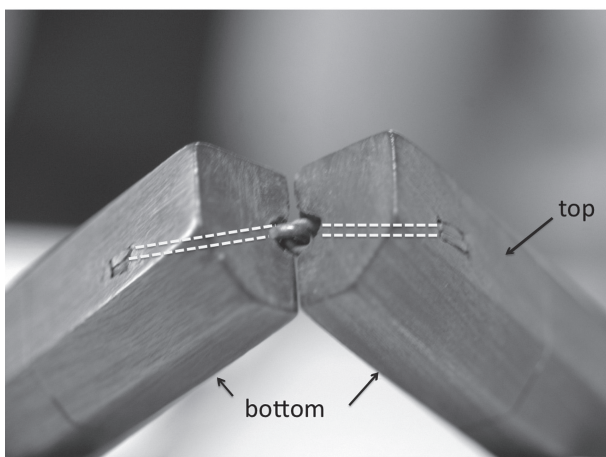
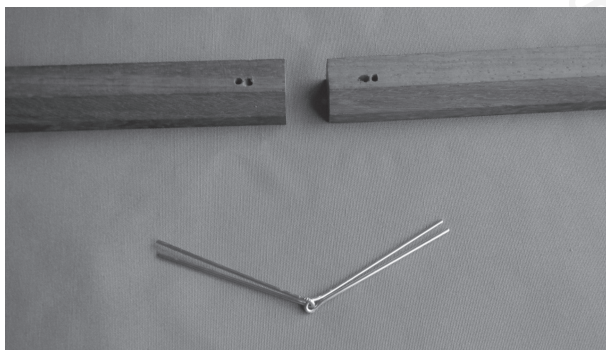


FIGURE 4: HINGE OF THE GENUINE ROD AND THE HINGE COMPONENTS OF THE TRIAL REPRODUCTION (UPPER).

As shown in Figure 2, Surface D is the rear, and Surface E is the underside. Both are surfaces that touch the ground when the cubit rod is opened and when it is closed. Except for these two, all surfaces have tally marks etched on them. Except for the underside, all faces are polished to a shine. I will discuss below the traces of fine abrasions all across the underside. The hinge is made up of a pair of U-shaped wire loops (Figure 4). The top part of Figure 4 is a photograph of an attempted reconstruction of the cubit rod; to accommodate the hinge, it must have been necessary to create holes on the top of the hardwood rod in advance. A close inspection of the original hinge shows that the U-shaped wires were inserted toward the top surface from the underside corner of the rod; then their tips were bent and clinched into the rods just beneath the top surface (Figures 4 and 7). From observation, I realized that the locations of the repair marks visible on the top of the rod and the underside corners of the ends coincide with the locations of the hinge holes. It seems possible that the repair marks indicated by the arrows in Figures 1 and 2 are signs of trial and error from when the artisan reconstructed the hinge. We can surmise that the hinge of the folding cubit rod would have been an important issue for the craftsmen.

Because the hinge of the folding cubit rod in this study was diligently and repeatedly constructed through trial and error to satisfy two contradictory requirements, it is apparently unique among known rods from ancient and modern times.

First, I wish to summarize my observations about the folding mechanism. The axis of revolution must be placed on the outside of the rod for it to be folded. Perhaps this can be easily understood by looking at the hinge of any nearby door. If the axis of revolution is placed inside the thickness of the measure, the measuring rod will interfere with itself and will by no means be able to fold. On the other hand, if the hinge protrudes from the underside when the rod is open, it will rattle and be unstable. One can imagine that the architect Kha would not have accepted such an unstable and awkward instrument. Artisans who sought a rod with perfect contact even when open would have had to make it with a hinge that somehow does not protrude from the underside.

As shown by the arrows in the right side of Figure 5, the folding rod's axis of rotation is the contact point of the two wires composing the hinge. The axis of rotation must be placed on the outside in order to fold, but if it protrudes, it becomes a problem when in use. I suggest that this point was the most serious issue.

I consider that at the beginning, the intention was to set the axis of rotation as close as possible to the underside. However, despite only being 1.8mm thick, the wires would have protruded. This would have been a problem. I attempted to reconstruct it, and confirmed that even a protrusion of 1mm causes it to rattle, and while it is not completely unusable, its stability is impaired. Here we must bear in mind that the artisans by no means gave up on creating a good instrument for Kha. Whatever difficulties they had, they somehow tried to achieve their goal.

Regarding the experiment that the artisans may have conducted to fulfill two of the contradictory conditions, I have shown my conjecture in Figure 5.

First the hinge was set on the outside as in (1). I think that play was created as well. However, while (1) could fold, it became a problem because the hinge protrudes from the underside. It



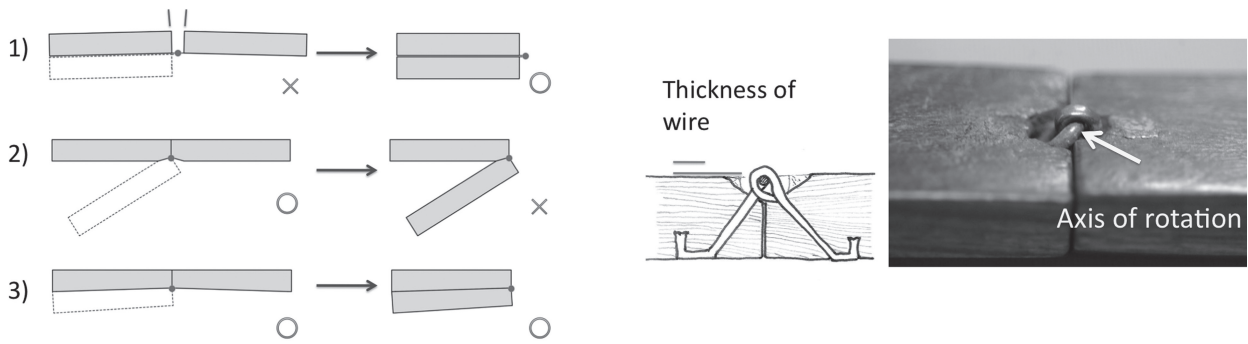


FIGURE 5: ASSUMED TECHNIQUES USED BY ARTISANS AND VIEW OF THE UNDERSIDE.

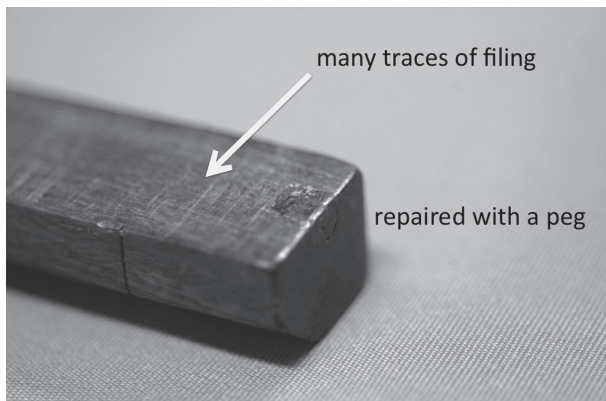


FIGURE 6: VIEW OF THE UNDERSIDE, LEFT-HAND ASPECT.

may be guessed that there were several subsequent attempts, but I conjecture that a gap was made by whittling the area around the hinge as shown in (2). Upon careful examination of the hinge surroundings, one can see that the edge of the measuring rod was slightly whittled. Nevertheless, this contradicts the principle of folding. The artisans whittled the area around the hinge and tried to embed the hinge into the thickness of the measuring rod, but because the axis of rotation was placed within the body of the rod, it could not fold and did not meet the essential requirement of being foldable. Thus, solution (3) was discovered. They created a slight gradient along the length of the underside toward the hinge.

When I observed the rod in the closed position, I noticed an extremely long and narrow triangle between the rods. It is conjectured that a slight slope, unnoticeable at first glance, was placed uniformly along the entire underside. Keeping the length of the rod and the thickness of the wires in mind, the gradient of the bottom surface is probably  $2/1000$  or  $3/1000$ . When I made a scale drawing and simulated an actual rotation on paper, it became clear that the hinge would still require some improvement.

Upon further observation, I discovered that the loops of the wires used to make the hinge are slightly distorted. When I took this point into consideration, I

succeeded in simulating rotation with method (3). I believe that the final key to solving the problem is the movement of the axis of revolution. The axis of rotation was moved slightly by the distortion of the loops. Figure 7 schematizes my conjecture concerning the principle of the clever hinge. I was thinking that I would like to create a model for verification, but when I asked artisan acquaintances, I was told that it is different from their usual work, and that they did not know how much time it would take to make the subtle adjustments. Currently I am waiting for a chance to make a reconstruction.

Finally, I would like to mention the signs of abrasion hidden on the underside (Figure 6). For the artisans to make the clever hinge, they would have needed to make a uniform and gentle slope on the bottom surface, but I imagine that this was done with a file because it was very delicate work (Killen 1994: 33; Lucas and Harris 1962: 449; Sliwa 1975: 38). I surmise that the countless abrasion marks are perhaps the traces of filing work. Regarding these abrasion marks, there is the explanation that they came about when Kha used the measure on top of stone. Certainly that is a possibility. However, there are almost no abrasions on the rear side, which could be considered a contact surface similar to the underside. Perhaps the reason for that must also be considered.

Yet, as with the rulers that we use every day, the special beveled surface with a pentagonal section is a useful shape

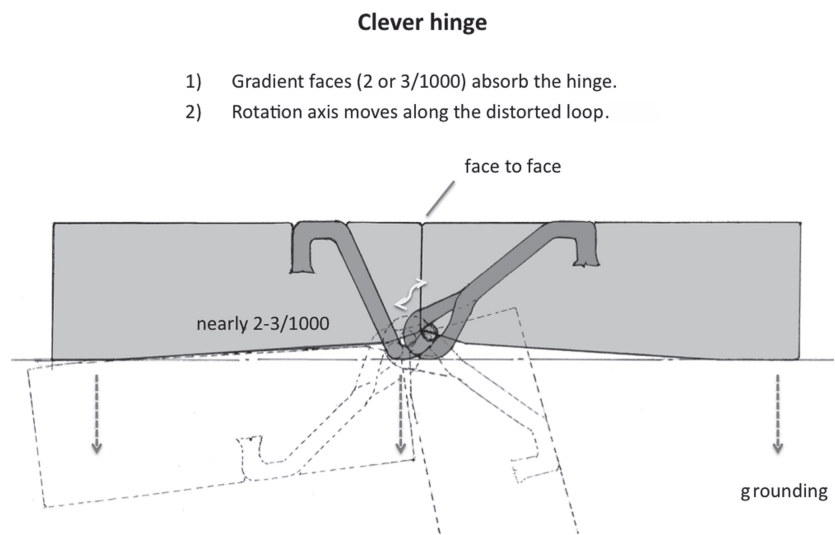


FIGURE 7: DIAGRAM OF THE HINGE DESIGN.

Why the beveled face was made ?

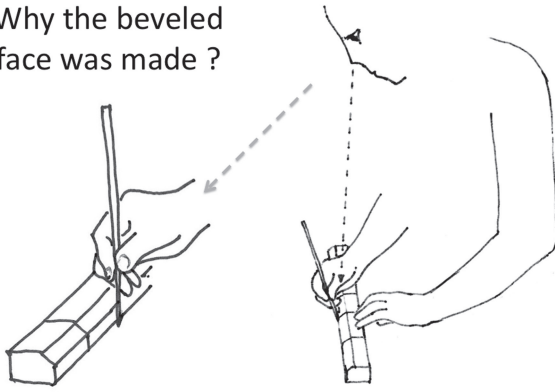


FIGURE 8: FUNCTION OF THE BEVELED FACE.

for making marks. Exactly as shown in Figure 8, it prevents the edge of the ruler from obstructing one's line of sight, and even when moving a hand holding a writing implement along the ruler it is easy to use and does not touch the edge. It may be that this was one reason for its pentagonal cross section.

### Conclusion

I measured not only the total length but each interval of S.8391 and discovered traces of trial and error in remaking the hinge. I also stated points that suggest that the divisions, which were thought to be inaccurate, were caused by adjustments to the folding mechanism.

The folding rod is easy to use, either open or closed, and one can imagine Kha carrying it in his hand and using it at the destination site to measure approximate sizes. It can be used as a one-cubit as well as a half-cubit measure, and the first palm on the left side can measure digits, which indicates that this instrument was a prized possession that could also measure the dimensions of objects encountered in daily life. The numerical values of the length of the segments of rod vary according to how the ruler was used, thus illustrating the high degree of precision achieved by the Egyptian artisan.

In this study, I discovered that the clever hinge that makes this cubit rod possible meets two contradictory requirements to achieve the folding mechanism and to make the rod easy to use. As an instrument that Kha used on site, we can guess how important ease of use was, and we can recognize once again how special the owner of this tool was from the time and effort required to produce it.

As I mentioned before, King Tutankhamun has the unique folding bed. It is very interesting that among the artifacts of the architect Kha, who served the grandfather of Tutankhamun, there was already an item with a folding mechanism that was created with passion.

### Acknowledgments

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